International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

Crossref

IJBSM January 2022, 13(1):81-92 Print ISSN 0976-3988 Online ISSN 0976-4038 **Article** AR2297

Research Article *Natural Resource Management*

DOI: HTTPS://DOI.ORG/10.23910/1.2022.2297

Genetic Association, Variability and Path Studies for Yield Components and Quality Traits of High Yielding Rice (*Oryza sativa* L.) Genotypes

K. Rukmini Devi, Y. Hari, B. Sathish Chandra and K. Rajendra Prasad

Regional Agricultural Research Station, Professor Jayashankar Telangana State Agricultural University , Mulugu road, Warangal, Telangana (506 007), India

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Corresponding rukminirars@gmail.com

0000-0001-8005-4815

ABSTRACT

A field study was conducted during *Kharif*, 2017 (July–October) to evaluate seventy-one diverse genotypes for variability with regards to yield, yield components and quality traits in addition to correlation and path studies at Regional Agricultural Research station, Warangal, Telangana State, India. Estimates of variability, heritability and genetic advance as percent of mean were noted for all the traits, which revealed that high PCV (28.56%) and GCV (24.37%) values were recorded by grain yield plant^{-1}, panicle density (28.47% and 20.06%). volume expansion ratio, filled seeds panicle^{-1}. panicle weight, head rice recovery, plant height and days to 50% flowering which indicated selection for these traits will be effective, while high heritability coupled with genetic advance as percent of mean was recorded by days to 50% flowering (97.8% and 23.7%), kernel length after cooking (95% and 32.4%) and test weight (93.0% and 52%) respectively and these characters could be improved through selection. Hulling recovery recorded low genetic advance as percent of mean. Significant positive association was observed for grain yield plant^{-1} with days to 50% flowering, plant height, effective tillers, panicle density, panicle weight, filled seeds panicle^{-1}, test weight, hulling percent, milling percent, head rice recovery and kernel length suggesting importance should be given to these characters, during selection. Path analysis showed that filled seeds panicle^{-1} (1.702) followed by kernel elongation ratio, panicle weight, milling percent and water uptake had direct effect of these traits on grain yield indicated their importance in determining the complex character and therefore should be kept in mind while practicing selection aimed at improving the grain yield.

KEYWORDS: Correlation, path, quality traits, rice yield, variability

Citation* (VANCOUVER)*: Devi et al., Genetic Association, Variability and Path Studies for Yield Components and Quality Traits of High Yielding Rice (*Oryza sativa* L.) Genotypes. *International Journal of Bio-resource and Stress Management,* 2022; 13(1), 81-92. HTTPS://DOI.ORG/10.23910/1.2022.2297.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 21st April 2021 RECEIVED in revised form on 20th November 2021 ACCEPTED in final form on 10th January 2022 PUBLISHED on 31st January 2022

1. INTRODUCTION

Rice is the staple food for about 2.5 billion of World population which may escalate to 4.6 billion by the year 2050. Rice is one of the significant cereal commodities and fulfills the nutritional requirements of half of the World's population (Lopez, 2008). It occupies a pivotal place in Indian agriculture as it is a staple food for more than70% of population and source of lively hood for about150 million rural households. More than 2000 modern varieties have been commercially released in south and South east Asia over the past 40 years. Selection of promising genotypes in breeding program is based on various criteria, most importantly final crop yield and quality (Kozak et al., 2007; Rukminidevi et al., 2020). The progress in breeding for yield and its contributing characters of any crop is polygenically controlled, environmentally influenced and determined by the magnitude and nature of their genetic variability (Wright, 1935). Paradigm shift in the rice (*Oryza sativa*) breeding strategy from quantity centered approach to quality-oriented effort was inevitable since India has not only become self sufficient in food grains production but also in the record largest exporter of quality rice in the world (Sreedhar et al., 2005). Rice is the only cereal crop cooked and consumed mainly as whole grains and quality considerations are more important (Hossain et al., 2009). A wide range of genetic variability has been reported for quality traits in the past, but still there exists untapped genetic variability in germplasm which is of paramount importance in releasing the potential parents so as to get maximum heterosis and superior recombinants with respect to quality components. The genetic characters are mostly governed by polygenes which are highly influenced by environment. Moreover, knowledge of heritability is highly essential for selection-based improvement, as it indicates the extent of transmissibility of a character into future generations (Sabesan et al., 2009). In a similar manner high genetic advance coupled with high heritability offers most effective condition for selection of a specific character. The base for any crop improvement relies on availability of amount and direction of genetic association of the traits, the base population and adopt of appropriate selection techniques (Rani et al., 2016; Adhikari et al., 2018). In order to understand the genetic variability of yield contributing characters, relationship among them and their relationship with yield are prerequisite to execute any breeding programme. The correlation coefficient may also help to know characters with little or no importance in the selection programme (Singh et al., 2014). The genotypic correlation on the other hand, which represents the genetic portion of the phenotypic correlation, is the only one of inheritable nature and therefore, used to orient breeding programmes. The existence of correlation may be attributed to the presence of linkage or pleiotropic effect of genes or physiological and development relationship or environmental effect or in combination of all (Oad et al., 2002). Correlation in grouping with path analysis would give a better insight into cause and effect relationship between different pairs of characters (Jayasudha and Sharma, 2010). Partitioning of total correlation into direct and indirect effects by path coefficient analysis helps in making the selection more effective (Priya and Joel, 2009). In agriculture ,path analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Malligan et al., 1990; Surek and Beser, 2003; Gupta et al., 2020). The present investigation was under taken to estimate genetic variability, heritability, genetic advance, correlation, direct and indirect effects for different yield components and quality traits among a set of 71 genotypes.

2. MATERIALS AND METHODS

The experiment was conducted during *kharif*, 2017 (July–October) at Regional Agricultural Research station, Warangal Telangana State, India. The experimental material Comprised of 71 rice genotypes (belongs to different agro ecological regions of India) and it was laid out in randomized block design with two replications. Each plot consists of 3 rows of 4m length. Thirty days old seedlings were transplanted with a spacing of 20×15cm between rows and plants at the rate of 20 plants per row. The crop was grown with the application of fertilizers NPK at the rate of 120:60:40 kg ha^{-1} respectively and the recommended package of practices were followed for raising healthy crop. A composite sample of 10 plants from the middle row was used to record observations on the plants for yield components like plant height (cm) effective tillers, panicle length (cm). panicle density, panicle weight (g), filled seeds $panicle^{-1}$, test weight (g) and yield $plant^{-1}$ (g) except days to 50% flowering which was computed on plot basis.

Data was recorded on Physical and chemical quality characters *viz* hulling percent(%) milling percent (%), head rice recovery (%), kernel length (mm), kernel width(mm), length /breadth ratio, kernel length after cooking (mm), kernel elongation ratio, alkali spreading value, water uptake (ml) and volume expansion ratio. Observations on hulling and milling were taken with the help of Satake Company make laboratory huller and polisher. Data on head rice recovery was recorded. Kernel length and kernel width of 10 whole milled rice were measured by means of dial caliper and length and breadth ratio was computed (Murthy and Swamy, 1967). Kernel elongation was determined by soaking 5 g of whole milled rice in 12 ml distilled water for 10 minutes and later cooked for 15 minutes in water bath. Observations on length and breadth of cooked kernels and elongation ratio were recorded with the help of graph sheet to quantity cooking traits and water uptake and volume expansion ratio by following the standard procedures. The treatment means for all the characters were subjected to analysis of variance techniques onthe basis of model proposed by Panse and Sukhatme (1961). The genotype and phenotypic variances were calculated as formulae proposed by Burton and Divane (1953). Heritability in broad sense h^2b and genetic advance as percent of mean were estimated by the formula as suggested by Hanson et al., (1956) and Johnson et al. (1955). The path and correlation coefficient analysis was done following method of Dewey and LU, (1959).

3. RESULTS AND DISCUSSION

3.1. Analysis of variance

Analysis of variance revealed highly significant differences among the genotypes for all the 21 yield components and quality traits indicating the existence of significant amount of variability among the characters studied (Table 1).

The genotype WGL 915 recorded maximum mean value of plant height (134.3 cm), panicle length (31.5 cm), panicle weight (9.98 g), while OR 2573-15 and WGL 915 for test weight (30.1g:28.5 g), JGL 21820 for filled grain panicle^{-1} (351), CR 3985-1 for yield plant^{-1} (37.8 g), YNP 9183 for milling percent (71.6%), WGL-347 for effective tillers (12.95), JR 206 for head rice recovery (60.5%) and MTU1236 for volume expansion ratio (3.35).

3.2. Genetic variability

The extent of variability for any characters is very important for the improvement of a crop through breeding. The estimates of genotypic variation (6^2g), phenotypic variation (6^2p), heritability and genetic advance, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) for various characters have been presented in Table 2. The extent of influence of environment on any character indicates the magnitude of the difference between the genotypic and phenotypic coefficient of variation. Large difference reflects high environmental influence while small difference reveals high genetic influence. The magnitude of

Table 1: Analysis of variance (mean squares) for grain yield and quality traits in rice (*Oryza sativa* L.)

Sl. No.	Characters	Replication (d.f=1)	Treatments (d.f=70)	Error (d.f=70)
1.	Days to 50% flowering	0.852113	140.3728**	1.4806
2.	Plant height (cm)	19.781690	151.6834**	13.9085
3.	Effective tillers	18.605350	3.011541**	1.418495
4.	Panicle length (cm)	10.547110	5.186660**	1.340398
5.	Panicle density	2.816901	11.590268**	1.041616
6.	Panicle weight(g)	0.193363	2.384041**	0.32780
7.	Filled seeds Panicle^{-1}	1104.33800	7427.899**	708.8666
8.	Test weight(g)	0.718380	34.203674**	1.246237
9.	Yield plant^{-1} (g)	12.245700	74.5956**	11.73184
10.	Hulling recovery (%)	74.856410	28.131817**	10.318123
11.	Milling recovery (%)	135.476700	80.91506**	14.6615
12.	Head rice recovery	0.375282	163.00992**	13.4485
13.	Kernel length (mm)	0.136959	0.633254**	0.023306
14.	Kernel width (mm)	0.013606	0.066587**	0.01284
15.	L/B ratio	0.176056	0.265531**	0.050771
16.	Kernel length after cooking (mm)	0.090761	1.311440**	0.033913
17.	Kernel breadth after cooking (mm)	0.019406	0.113316**	0.00843
18.	Kernel elongation ratio	0.023327	0.020186**	0.00323
19.	Alkali spreading value	0.693003	1.405978**	0.233380
20.	Water uptake	494.542300	5161.7354**	247.3993
21.	Volume expansion ratio	0.23.2835	0.574641**	0.073062

*: Significant at (p=0.05) level; **: Significant at (p=0.01) level

Table 2: Components of genetic parameters for yield and quality traits in rice (*Oriza sativa* L.)

Character	Mean	Range	PV	GV	PCV	GCV	Heritability in broad sense (%)	Genetic advance as percent of mean
Days to 50 % flowering		76-116	7.0.927	69.446	9.172	9.075	97.9	23.708
Plant height (cm)	115.6	86-124.6	82.796	68.887	7.869	7.178	83.2	17.284
Effective tillers	9.1	66-12.8	2.215	0.797	16.314	9.783	36.0	15.488
Panicle length (cm)	25.9	21.6-31.5	3.264	1.923	6.964	5.346	58.9	10.834
Panicle density	8.825	5-14.5	6.316	5.274	28.477	26.023	83.5	62.780
Panicle weight (g)	4.862	2.92-9.95	1.356	1.028	23.949	20.854	75.8	47.941
Filled seeds Panicle^{-1}	229.831	128.5-356.5	4068.383	3359.516	27.753	25.219	82.6	60.501
Test weight (g)	19.537	12.8-30.1	17.725	16.479	21.549	20.778	93.0	52.890
Yield plant^{-1} (g)	23.004	9.0-37.8	43.164	31.432	28.560	24.372	72.8	54.906
Hulling recovery (%)	76.763	68.0-88.23	19.225	8.907	5.712	3.888	46.3	6.986
Milling recovery (%)	62.730	40.6-73.5	47.788	33.127	11.020	9.172	69.3	20.167
Head rice recovery	43.133	21.7-60.45	88.229	74.781	21.777	20.049	84.8	48.728
Kernel length (mm)	5.206	7.37-6.47	0.328	0.305	11.005	10.607	92.7	26.991
Kernel width (mm)	1.642	1.33-2.23	0.040	0.027	12.140	9.985	67.7	21.683
L/B ratio	3.213	2.35-4.10	0.158	0.107	12.379	10.200	67.9	22.188
Kernel length after cooking (mm)	6.352	5.05-7.87	0.673	0.639	12.911	12.581	95.0	32.367
Kernel breadth after cooking (mm)	2.165	1.85-2.92	0.061	0.052	11.399	10.580	86.1	25.923
Kernel elongation ratio	1.221	0.93-1.55	0.012	0.008	8.861	7.540	72.4	16.936
Alkali spreading value	4.778	3.25-6.50	0.820	0.586	18.950	16.026	71.5	35.783
Water uptake	243.697	127.5-370.0	2704.567	2457.168	21.340	20.341	90.9	51.185
Volume expansion ratio	2.007	1.13-3.50	0.324	0.251	2 8.355	24.952	77.4	57.970

6^2p and 6^2g was high for the characters filled seeds panicle^{-1} (4068.38 and 3359.5) and lowest for kernel elongation ratio (0.012 and 0.008). The relative value of genotypic and phenotypic coefficient of variation provides important information on the magnitude of variation. In general phenotypic co efficient of variation (PCV) was higher than genotype coefficient of variation (GCV) in all the studied characters it indicates the presence of environmental influence to some degree on the phenotypic expression of the character, bur most part of the phenotypic coefficient of variation was contributed by the genotypic component. Also good correspondence was observed between PCV and GCV for all the characters. The difference between PCV and GCV was less for the characters day to 50% flowering, plant height, kernel breadth after cooking . Phenotypic coefficient of variation ranged from 5.71 (hulling %) to 28.56 (Grain yield plant^{-1}), while GCV ranged from 3.88 (hulling %) to 26.02 (panicle density).

High PCV and GCV values (>20) were recorded by yield plant^{-1} (28.56%) and 24.37%), panicle density (28.47% and 26.02%), volume expansion ratio (28.0 and 24.95), filled grains panicle^{-1}, (27.72 and 25.2), panicle weight (23.9 and 20.8), head rice recovery (21.77 and 20.04), test weight (21.5 and 20.77) and water uptake (21.34 and 20.34). Similar findings of high GCV by Hossain et al. (2015) for yield plant^{-1}, Nirmaladevi et al., (2015) for water uptake. Ganga shetty et al. (2013) for test weight, Chaudhari et al., (2007) for water uptake, Manjunatha et al. (2017) for filled grains panicle^{-1}, Hossain et al. (2020) for filled grains panicle^{-1} and grain yield plant^{-1}, Nirmala devi et al. (2015) for filled grains panicle^{-1}, grain yield plant^{-1} and test weight. Nirmala devi et al. (2015) also reported low PCV and GCV for volume expansion ratio and Konate et al. (2016) for panicle weight and test weight.

Low PCV and GCV values (<10%) were found for the characters *viz* hulling % (5.71%; 3.88%), panicle length (6.96%; 5.35%), plant height (7.86%; 7.17%), kernel elongation ratio (8.86%; 7.54%) and days 50% flowering (9.17%; 90.1%), milling recovery (11.02% :9.17%) respectively. Akanda et al. (1997). Kole et al. (2008), Aditya et al. (2013) observed low PCV and GCV values for days to 50% flowering, plant height, panicle length, Nirmala devi et al. (2015) also noticed low PCV and GCV values for hulling %. Vanaja and Babu (2006), Uma Devi et al. (2010) for days to 50% flowering, plant height, Hossain et al. (2008) and plant height for Aditya et al. (2013), lower GCV and PCV estimates indicates narrow genetic base for these traits. Improvement in these characters can be brought about by hybridization or induced mutagenesis to widen genetic base followed by pedigree selection in advanced generations. The PCV and GCV values recorded moderate (>10 <20) for the traits effective tillers (16.13%; 9.78%), kernel length after cooking (12.9%; 12.58%), kernel width (12.14%; 9.98%). kernel length (11.07% ; 10.60%) respectively were consistent with the finding of Nirmala devi et al. (2015) for kernel length, kernel breadth, length / breadth ratio, kernel length after cooking and kernel elongation ratio. This indicates the low existence of comparatively moderate variability for these traits which could be exploited for improvement through selection in advanced generation on the whole the close correspondence between the estimates of GCV and PCV for most of the traits indicated lower influence on the expression of traits which is also reflected by their high heritability values for most of the characters.

3.3. Heritability

Broad sense heritability is useful in selection of elite types from homozygous lines, where as narrow sense heritability is useful in selection of elite types from segregating populations. Heritability in broad sense includes both fixable (additive) and non fixable (dominant and epistatic) variances and also provides a good indication about the repeatability of the traits and help the plant breeder in selection of elite genotype form diverse genetic populations. The estimates of heritability for different characters ranged from 36% (effective tillers) to 97.9% (days to 50% flowering).

Although, the presence of high heritability value indicates the effectiveness of selection on the basis of phenotypic performance, it does not show any indication to the amount of genetic progress for selecting the best individual which is possible by using the estimate of genetic advance. Heritability estimates (above 70%) would be helpful in predicting genetic gain under selection than heritability estimates alone. In this study days to 50% flowering (97.9%), kernel length after cooking (95%), test weight (93%), kernel length (92.7%), water uptake (90.9%) kernel breadth after cooking (86.1%), head rice recovery (84%), panicle density (83.5%), filled seeds panicle^{-1} (83.6%), panicle weight (75.8%) and alkali spreading value (70.5%) respectively whereas panicle length, effective tillers, hulling recovery, milling recovery ,kernel width and length/width ratio recorded moderate to low heritability values which indicate the preponderance of additive gene action and such characters could be improved through selection. These observations in corroborate well with those of Hussain et al. (1989), Nirmala devi et al. (2015) for head rice recovery and water uptake, Singh et al. (2014) for test weight, Ravindra Babu et al. (2012) for filled grains panicle^{-1} and water uptake and Srivastava et al. (2017), Gupta et al. (2020) for filled seeds panicle^{-1},test weight and gran yield plant^{-1}, Manjunath et al. (2017) reported high heritability values for plant height and grain yield plant^{-1}.

3.4. Genetic advance

Genetic advance as percent of mean was high (>20) for 16 characters, panicle density (62.7%) filled seeds panicle^{-1} (60.5%) volume expansion ratio (56.9%), grain yield plant^{-1} (54.9%), test weight (52.8%) water uptake, head rice recovery, panicle weight alkali spreading value, kernel length etc, while moderate (10-20%) for plant height (17.28%) elongation ratio, effective tillers and panicle length and low genetic advance as present of mean was observed for hulling recovery. High estimates of heritability coupled with medium estimates of genetic advance was observed for plant height (83.3%; 17.2%) respectively rendering them unsuitable for improvement through selection.

In general, the characters that show high heritability with high genetic advance are controlled by additive gene action (Panse and Sukhatme, 1967) and can be improved though simple selection or progeny selection methods. Selection for the traits having high heritability and high genetic advance is likely to accumulate more additive genes leading to further improvement of their performance. Any indication to the amount of genetic progress for selecting the best individual which possible by using the estimate of genetic advance.

Heritability estimates (above 70%) along with genetic advance (above 20%) would be helpful in predicting gain under selection than heritability estimates alone. In this study days to 50% flowering (97.9%; 23.7%) kernel length after cooking (95%; 32.4%), test weight (93%; 52.8%), kernel length (92.7 %; 26.9%), water uptake, kernel breadth after cooking, head rice recovery filled seeds panicle^{-1}, panicle weight and alkali spreading value respectively which indicate the preponderance of additive gene action such character could be improved through selection. These observations corroborate well with those of Hossain et al.,

(2020) for filled grains panicle^{-1}, Manjunatha et al. (2017) for days to 50% flowering Hussain et al., (1989).Nirmala devi et al. (2015) for test weight, Kundu et al. (2008) for kernel length after cooking and Ravindra Babu et al. (2012), Rukminidevi et al. (2020) for filled grains panicle^{-1} and water uptake, days to 50% flowering and plant height by Hossain et al. (2015), plant height and effective tiller by Sabesan et al. (2009). In contrary high genetic advance and heritability for plant height was reported by Akinwale et al., (2011). The characters with high heritability with moderate or low genetic advance can be improved by intermating superior genotypes of segregating population developed from combination breeding (Samadia , 2005), Chouhan et al. (2014) and Pratap et al. (2018) for effective tillers, filled grains panicle^{-1}, test weight and yield plant^{-1}.

3.5. Correlation studies

Relationships among yield and yield contributing traits and quality traits through analysis of correlation among the studied traits of 71 rice genotypes are presented in Table 3. Correlation analysis among the yield, yield components and quality traits revealed that the genotypic correlation coefficients in most of the cases higher than their phenotypic correlation coefficients indicating the association was largely due to genetic reason. At both levels significant positive association was observed for gram yield plant^{-1} with days to 50% flowering, plant height, effective tillers, panicle density, panicle weight, filled seeds panicle^{-1}, test weight, hulling percent, milling percent. Head rice recovery kernel length, length/ breadth ratio, kernel length after cooking, alkali spreading value and water uptake had negative association with panicle length, kernel width, kernel elongation ratio and volume expansion ratio which was earlier supported by Devi et al. (2017), Krishnaveni et al. (2013) for effective tillers and it suggest that importance should be given to these traits while doing selection. Days to 50% flowering had significant positive correlation with head rice recovery and alkali spreading value while significant negative correlation with test weight, kernel length, length/breadth ratio and kernel elongation ratio. Days to 50% flowering had significant positive correlation with head rice recovery which was earlier supported by Venkata lakshmi et al. (2014). Similar results were reported by Gupta et al., (2020) and Hossain et al. (2020) for filled seeds panicle^{-1}, Konate et al. (2016) for days to 50% flowering, plant height and panicle weight, Srivastava et al. (2017) for test weight and yield plant^{-1} The association expressed by panicle weight, filled seeds panicle^{-1} and water uptake was significant and positive at phenotypic and genotypic level which was supported by Srijan et al. (2016) for the character panicle length and number of filled grainspanicle^{-1}, significant positive correlation was expressed by panicle weight, test weight, kernel length and kernel breadth after cooking with panicle length. It suggests that priority should be given to those traits while making selections for yield improvement. Filled seeds panicle^{-1} had significant positive association with hulling percent and head rice recovery but recorded significant negative value with test weight, kernel width and kernel length after cooking, kernel breadth after cooking and alkali spreading value. The correlation of kernel length was positive and significant with kernel width, length/ breadth ratio, kernel length after cooking, kernel breadth after cooking, alkali spreading value, water uptake and volume expansion ratio at both phenotypic as well as genotypic level. The correlation coefficient may also help to know characters with little or no importance in the selection programme (Singh et al., 2014).

3.6. Path analysis

The estimates of correlation coefficient revealed only the relationship between yield and yield associated characters, but did not show the direct and indirect effects of different traits on yield perse. This is because the attributes which are in association do not exist by themselves, but are linked to other components. The path coefficient analysis suggested by Dewey and Lu (1959) specified the effective measure at direct and indirect causes of association and also depicts the relative importance of each factor involved in contributing to the final product that is yield. Path coefficient analysis using grain yield as dependent variable and other characters as independent variables is presented in Table 4. Filled seeds panicle^{-1} (1.702) followed by kernel elongation ratio (1.586), panicle weight (1.563), milling percent (0.949) and water uptake (0.564) had direct effect on grain yield plant^{-1} indicated their importance in determining this complex character and therefore should be kept in mind while practicing selection aimed at improving the grain yield. Similar results were also reported by Gawal et al. (2006), Jayasudha and Sharma (2010) and Hossain et al. (2020) for filled grains panicle^{-1}, panicle density, test weight, hulling percent, days to 50% flowering and panicle length expressed negative direct effect on grain yield plant^{-1}. Days to 50% flowering had negative direct effect on grain yield plant^{-1} but it had positive indirect effect on grain yield through test weight, kernel length, length/breadth ratio, kernel length after cooking and kernel elongation ratio.

Filled grains panicle^{-1} expressed positive indirect effect on grain yield through hulling percent, milling percent, head rice recovery, days to 50% flowering, plant height and panicle weight. The indirect expression of milling percent on grain yield was through panicle length, filled seeds panicle^{-1}, test weight, kernel breadth after cooking, water uptake and volume expansion ratio, panicle length expressed positive indirect effect on grain yield through panicle density, milling percent, head rice recovery and alkali spreading value, while

Table 3: Phenotypic and genotypic correlation coefficient for yield traits in rice (*Oryza sativa* L.)

Characters		DF	PH	ET	PL	PD	PW	FS	TW	HP	MP
Days to 50 % flowering	P	1.0000	0.1428	0.1099	0.1067	0.0818	0.1374	0.1336	-0.1002	0.1160	0.1645
	G	1.0000	0.1728	0.1405	0.1467	0.0914	0.1609	0.1517	-0.0970	0.1561	0.2203
Plant height (cm)	P		1.0000	0.1145	0.4485**	0.1190	0.3948**	0.1947*	0.1158	0.1001	-0.0396
	G		1.0000	0.0470	0.5750	0.1553	0.4928	0.2380	0.1274	0.0970	0.0491
Effective tillers	P			1.0000	-0.0440	0.0508	-0.1494	0.0478	-0.0840	0.0980	0.0945
	G			1.0000	0.0258	0.0565	-0.2723	0.1155	-0.1510	-0.1730	0.2643
Panicle length (cm)	P				1.0000	-0.1585	0.3077**	0.0502	0.2404**	0.0350	-0.2952**
	G				1.0000	-0.1740	0.4770	0.0162	0.3240	0.0681	0.4833
Panicle density	P					1.0000	0.3915**	0.9532**	-0.5590**	0.1057	0.1821
	G					1.0000	0.4387	0.9583	-0.6025	0.2676	0.2256
Panicle weight	P						1.0000	0.4518**	0.2415**	0.1886*	-0.0987
	G						1.0000	0.5176	0.2486	0.3231	-0.1206
Filled grains panicle^{-1}	P							1.0000	-0.5337**	0.1703*	0.0955
	G							1.0000	-0.5742	0.3189	0.1075
Test weight(g)	P								1.0000	-0.0340	-0.1194
	G								1.0000	-0.0634	-0.1508
Hulling recovery (%)	P									1.0000	0.3482**
	G									1.0000	0.6040
Milling recovery (%)	P										1.0000
	G										1.0000
Grain yield plant^{-1} (g)	P	0.0144	0.2479	0.1543	0.0361	0.0922	0.2023	0.1139	0.1358	0.1353	0.1173
	G	0.0079	0.3088	0.3452	-0.0332	0.0626	0.2013	0.0636	0.1725	0.2668	0.1426

Table 3: Continue...

Characters		HRR	KL	KW	L / B ratio	KLAC	KBAC	KER	ASV	WU	VER
Days to 50 % flowering	P	0.1656*	-0.0499	0.1431	-0.1398	-0.0524	0.0323	-0.0120	0.2898**	0.1176	0.0529
	G	0.1825	-0.0548	0.1877	-0.1818	0.0501	0.0328	-0.0021	0.3312	0.1283	0.0591
Plant height (cm)	P	0.0102	0.1191	0.1053	0.0239	0.0921	0.1087	0.0382	-0.3390	0.1925*	-0.0252
	G	0.0188	0.1418	0.1377	0.0442	0.1195	0.1450	0.0616	-0.0898	0.2162	-0.0621
Effective tillers	P	0.1546	-0.0730	-0.0876	0.0078	-0.1088	-0.1745*	-0.0434	0.0383	0.0459	0.0151
	G	0.3142	-0.1538	0.2480	-0.0086	-0.1412	-0.2810	-0.0234	0.0356	0.0833	-0.0900
Panicle length (cm)	P	-0.2398	0.2632**	0.1551	0.0971	0.1512	0.2245**	-0.0511	-0.0493	0.0424	0.0338
	G	-0.3364	0.3039	0.3008	0.0764	0.2045	0.2688	-0.0109	-0.1354	0.0222	0.0522
Panicle density	P	0.3306**	-0.4522**	-0.2198**	-0.1627	-0.3327**	-0.1150	0.1018	0.0056	-0.0023	-0.0270
	G	0.3650	-0.0055	-0.2909	-0.2165	-0.3631	-0.1303	0.1463	0.1035	-0.0163	-0.0458
Panicle weight	P	-0.0544	0.1006	0.1942*	-0.0867	0.1039	0.3275**	0.0734	0.0455	0.0047	0.0494
	G	0.0694	0.1431	0.2651	-0.1232	0.1378	0.4119	0.0676	0.0652	-0.0104	-0.0026
Filled grains panicle^{-1}	P	0.2856**	-0.4164**	-0.1923*	-0.1553	-0.3106**	-0.0672	0.1032	-0.0078	-0.0516	-0.0443
	G	0.3058	0.9754	-0.2476	-0.2146	-0.3462	-0.0898	0.1480	0.0902	-0.0677	-0.1533

Table 3: Continue...

Characters		HRR	KL	KW	L / B ratio	KLAC	KBAC	KER	ASV	WU	VER
Test weight(g)	P	-0.3996**	0.7400**	0.3740**	0.2444**	0.6243**	0.3125**	-0.0012	0.1856*	0.1088	0.1343
	G	-0.4502	0.8018	0.4785	0.3258	0.6734	0.3507	0.0038	0.1859	0.1174	0.1367
Hulling recovery (%)	P	0.1463	-0.1346	-0.0701	-0.0468	-0.1319	-0.1378	0.0439	0.1310	-0.0721	-0.3052**
	G	0.1833	-0.1619	-0.1216	-0.0243	-0.0942	-0.2034	-0.0186	0.3056	-0.0929	-0.4233
Milling recovery (%)	P	0.4975**	-0.1001	-0.1317	0.0188	-0.0749	-0.2022*	-0.0050	0.2893**	0.0748	-0.0265
	G	0.5344	-0.1534	-0.2211	0.0581	-0.0942	-0.2419	0.0596	0.4269	0.0967	0.0010
Head rice recovery (%)	P	1.0000	-0.3463**	-0.1113	-0.1110	-0.2451**	-0.1093	0.0892	-0.0280	0.1258	-0.1093
	G	1.0000	-0.4029	-0.1495	-0.1693	-0.2613	-0.1238	0.1379	0.0077	0.1667	-0.0329
Kernel length (mm)	P		1.0000	0.3377**	0.5720**	0.7448**	0.4089**	-0.1501	0.2636**	0.3066**	0.2776**
	G		1.0000	0.4093	0.6533	0.7939	0.4670	-0.0744	0.3284	0.3346	0.3315
Kernel width (mm)	P			1.0000	-0.4798**	0.3942**	0.5298**	0.1695	0.1388	0.1783*	0.2438**
	G			1.0000	-0.4056	0.4808	0.7425	0.2355	0.3082	0.2412	0.3072
L/B ratio	P				1.0000	0.2774	-0.0639	-0.3076**	0.0972	0.1430	0.0037
	G				1.0000	0.3511	-0.1368	-0.3184	0.0722	0.1704	0.0172
Kernel length after cooking (mm)	P					1.0000	0.6199**	0.5240**	0.3797**	0.3613**	0.416**
	G					1.0000	0.6574	0.5455	0.4832	0.3886	0.4832
Kernel breadth after cooking (mm)	P						1.0000	0.4024**	0.1760*	0.2834**	0.3430**
	G						1.0000	0.4374	0.2232	0.3309	0.4317
Kernel elongation ratio	P							1.0000	0.2200**	0.1466	0.2506**
	G							1.0000	0.3444	0.1806	0.3250
Alkali spreading value	P								1.0000	0.2099*	0.4431**
	G								1.0000	0.2419	0.5056
Water uptake (ml)	P									1.0000	0.3590**
	G									1.0000	0.4033
Volume expansion ratio	P										1.0000
	G										1.0000
Grain yield plant^{-1} (g)	P	0.0960	0.1690	0.0303	0.1543	0.0875	0.0214	-0.0847	0.0531	0.1663	-0.0343
	G	0.1001	0.1945	-0.0355	0.2544	0.9040	0.0025	-0.0890	0.1296	0.1777	-0.0013

effective tillers had indirect positive effect through filled seeds panicle^{-1}, hulling percent, milling percent, length / breadth ratio, kernel breadth after cooking, water uptake and volume expansion ratio. The indirect expression of head rice recovery on grain yield was through panicle length, panicle weight, filled seeds panicle^{-1}, milling percent, kernel breadth after cooking, water uptake and volume expansion ratio, panicle weight had high indirect effect on grain yield plant^{-1} though filled seeds panicle^{-1}, test weight, hulling percent. Panicle weight had high in direct effect on grain yield plant^{-1} through filled seeds panicle^{-1}, test weight, hulling percent, head rice recovery, kernel length, kernel width, kernel length after cooking, kernel breadth after cooking and kernel elongation ratio. The indirect effect of effective tillers on grain yield was positive through filled seeds panicle^{-1}, hulling percent, milling percent, length/ breadth ratio, kernel breadth after cooking, water uptake and volume expansion ratio.

Table 4: Phenotypic and genotypic path coefficient analysis of yield traits in rice (*Oryza sativa* L.)

		DF	PH	ET	PL	PD	PW	FS	TW	HP	MP	HRR
Days to 50 % flowering	P	-0.0925	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.009	-0.01	-0.02	-0.02
	G	-0.5647	-0.1	-0.08	-0.08	-0.05	-0.09	-0.09	0.055	-0.09	-0.12	-0.01
Plant height (cm)	P	0.0253	0.177	0.02	0.08	0.021	0.07	0.035	0.021	0.018	-0.01	0.002
	G	-0.012	-0.07	-0	-0.04	-0.01	-0.03	0.017	-0.01	-0.01	0.003	-0
Effective tillers	P	0.0151	0.016	0.138	-0.01	0.007	-0.02	0.007	-0.01	0.014	0.013	0.021
	G	-0.0084	-0	-0.06	-0	-0	0.016	-0.01	0.009	0.01	-0.02	-0.02
Panicle length (cm)	P	-0.0236	-0.01	0.01	-0.22	0.035	-0.07	-0.01	-0.05	-0.01	0.065	0.053
	G	-0.0344	-0.13	-0.01	-0.23	0.042	-0.11	-0	0.076	0.016	0.113	0.079
Panicle density	P	-0.0515	-0.08	-0.03	0.1	-0.64	-0.25	-0.6	0.352	-0.1	-0.11	-0.21
	G	-0.2562	0.435	-0.16	0.3	-2.8	-1.23	-2.69	1.689	0.75	-0.63	-1.02
Panicle weight	P	0.0186	0.053	-0.02	0.042	0.053	0.135	0.061	0.033	0.026	-0.01	0.007
	G	0.2514	0.77	-0.43	0.743	0.685	1.563	0.809	0.388	0.505	-0.19	0.109
Filled grains panicle^{-1}	P	0.1001	0.146	0.036	0.038	0.715	0.339	0.75	-0.4	0.128	0.072	0.214
	G	0.2581	0.405	0.197	0.028	1.631	0.881	1.702	-0.98	0.543	0.183	0.52
Test weight (g)	P	-0.0151	0.017	-0.01	0.036	-0.08	0.036	-0.08	0.15	-0	0.018	-0.06
	G	0.1283	-0.17	0.2	-0.43	0.796	-0.33	0.759	-1.32	-0.08	0.199	0.595
Hulling recovery (%)	P	0.0091	0.007	0.008	0.002	0.012	0.015	0.013	-0	0.078	0.027	0.012
	G	-0.1734	-0.11	0.193	-0.08	-0.3	-0.36	-0.35	0.07	-1.11	-0.67	-0.2
Milling recovery (%)	P	0.0086	-0	0.005	-0.01	0.01	-0.01	0.005	-0.01	0.018	0.052	0.026
	G	0.2091	-0.05	0.209	-0.45	0.214	-0.15	0.102	-0.14	0.577	0.949	0.507
Head rice recovery (%)	P	0.0123	0.0008	0.011	-0.02	0.025	0.004	0.021	-0.03	0.011	0.037	0.074
	G	-0.013	-0	-0.02	0.025	-0.03	0.005	0.023	0.034	-0.01	-0.04	-0.08
Kernel length (mm)	P	0.0247	-0.06	0.038	-0.14	0.233	-0.05	0.215	-0.38	0.069	0.052	0.179
	G	-0.203	0.525	-0.57	1.126	-1.87	0.53	-1.76	2.971	-0.6	-0.57	-1.49
Kernel width (mm)	P	0.0218	0.016	-0.01	0.024	-0.03	0.03	-0.03	0.057	-0	-0.02	-0.02
	G	-0.1257	-0.09	0.15	-0.2	0.195	-0.18	0.166	-0.32	0.081	0.148	0.1
L/B ratio	P	-0.0278	0.005	0.016	0.019	-0.03	-0.02	-0.03	0.049	-0.01	0.004	-0
	G	0.2065	-0.05	0.01	-0.09	0.246	0.14	0.244	-0.37	0.028	-0.07	0.192
Kernel length after cooking (mm)	P	-0.03	0.053	-0.06	0.087	-0.01	0.06	-0.18	0.358	-0.08	-0.04	0.141
	G	0.1221	-0.29	0.344	-0.5	0.885	0.336	0.844	-1.64	0.346	0.23	0.637
Kernel breadth after cooking (mm)	P	-0.002	-0.01	0.011	-0.01	0.007	-0.02	0.001	-0.02	0.008	123	0.007
	G	-0.0243	-0.11	0.208	-0.2	0.097	-0.31	0.067	-0.26	0.151	0.179	0.092
Kernel elongation ratio	P	0.0059	-0.02	0.02	0.026	-0.05	-0.03	-0.05	6E-04	-0.02	-0	-0.04
	G	-0.0033	0.098	-0.04	-0.02	0.232	0.072	0.235	0.006	-0.03	-0.09	-0.22
Alkali spreading value	P	-0.0004	0	-0.001	0.001	0	-0.00	0.000	-0.00	-0.00	0.004	0
	G	0.2346	-0.06	0.025	-0.1	0.073	0.046	0.063	0.131	0.215	0.3	0.005
Water uptake (ml)	P	0.0182	0.03	0.007	0.007	-0	7E-04	0.008	0.017	-0.01	0.012	0.02
	G	0.0721	0.121	0.047	0.013	-0.01	-0.01	-0.04	0.066	-0.05	0.054	0.094
Volume expansion ratio	P	-0.0024	0.001	7E-04	-0	0.001	-0	0.002	-0.01	0.014	0.001	0.005
	G	-0.0551	0.058	0.084	-0.05	0.043	0.006	0.05	-0.13	0.395	-0	0.186
Grain yield plant^{-1} (g)	P	0.0144	0.248	0.154	0.036	0.092	0.202	0.114	0.136	0.135	0.117	0.1
	G	0.0079	0.309	0.345	-0.03	0.063	0.201	0.064	0.173	0.267	0.143	0.1

Table 4: Continue...

	KL	KW	L/B ratio	KLAC	KBAC	KER	ASV	WU	VER
Days to 50 % flowering	0.004	-0.01	0.0129	0.005	-0.003	0.0012	-0.03	-0.01	-0.005
	0.031	-0.11	0.1027	0.028	-0.019	0.0012	-0.19	-0.07	-0.033
Plant height (cm)	0.021	0.019	0.0042	0.016	0.019	0.0068	-0.01	0.034	-0.005
	0.01	-0.01	-0.003	-0.01	-0.01	-0.004	0.006	-0.02	0.004
Effective tillers	-0.01	-0.01	0.0011	-0.02	0.024	-0.006	0.005	0.006	-0.002
	0.009	0.013	0.0005	0.008	0.017	0.0014	-0	-0.01	0.005
Panicle length (cm)	-0.06	-0.03	-0.0215	-0.33	-0.05	0.0013	0.011	-94	-0.008
	-0.07	-0.07	-0.0179	-0.05	-0.063	0.0025	0.032	-0.01	-0.012
Panicle density	0.249	0.139	0.1025	0.21	0.073	-0.064	-0	0.002	0.002
	1.417	0.815	0.6068	1.018	0.365	-0.41	-0.29	0.046	0.129
Panicle weight	0.014	0.026	-0.0117	0.014	0.044	0.0099	0.006	0.0006	0.007
	0.224	0.415	-0.1926	0.215	0.644	0.1056	0.102	-0.02	-0.009
Filled grains panicle^{-1}	-0.31	-0.14	-0.1164	-0.23	-0.05	0.0733	-0.01	-0.04	0.032
	-0.81	-0.42	-0.3652	-0.59	-0.153	0.2518	0.153	-0.12	-0.091
Test weight (g)	0.111	0.056	0.0367	0.094	0.047	-2E-04	0.279	0.016	0.02
	-1.06	-0.63	-0.4307	-0.89	-0.464	-0.005	-0.25	-0.16	-0.181
Hulling recovery (%)	-0.01	-0.01	-0.0037	-0.01	-0.011	0.0038	0.01	-0.01	-0.024
	0.18	0.135	0.027	0.158	0.226	0.0207	-0.34	0.103	0.47
Milling recovery (%)	-0.01	-0.01	0.001	-0	-0.006	-3E-04	0.151	0.004	-0.001
	-0.15	-0.21	0.0552	-0.09	-0.23	0.0566	0.405	0.092	9E-04
Head rice recovery (%)	-0.03	-0.01	-0.0082	-0.02	-0.008	0.0066	-0	0.009	-0.008
	0.03	0.011	0.0127	0.02	0.009	-0.01	-0	0.013	0.007
Kernel length (mm)	-0.52	-0.17	-0.2952	-0.38	-0.211	0.0774	-0.14	0.153	-0.143
	3.706	1.517	2.4209	2.942	1.731	-0.276	1.217	1.24	1.228
Kernel width (mm)	0.052	0.153	-0.0732	0.06	0.081	0.0259	0.021	0.027	0.037
	0.274	-0.67	0.2715	-0.32	-0.497	-0.016	-0.2	0.162	-0.206
L/B ratio	0.114	-0.1	0.1991	0.055	-0.013	-0.061	0.019	0.029	7E-04
	-0.74	0.461	-1.3652	-0.4	0.155	0.3618	-0.08	-0.19	0.02
Kernel length after cooking (mm)	0.427	0.226	0.1592	0.574	0.356	0.3006	0.218	0.207	0.239
	-1.94	-1.17	-0.8559	-2.44	-1.602	-1.33	-1.18	-0.95	-1.178
Kernel breadth after cooking (mm)	-0.02	-0.03	0.0039	-0.04	-0.061	-0.024	-0.01	-0.02	-0.021
	-0.35	-0.55	0.1014	-0.49	-0.741	-0.324	-0.17	-0.25	-0.32
Kernel elongation ratio	0.069	-0.08	0.1419	-0.24	-0.185	0.4605	-0.1	-0.07	-0.115
	-0.12	0.374	-0.505	0.865	0.694	1.5861	0.548	0.286	0.515
Alkali spreading value	-0.004	-0.00	-0.0001	-0	-0.0002	-0.0003	-0	-0	-0.0006
	0.231	0.216	0.0507	0.339	0.157	0.2417	0.702	0.17	0.355
Water uptake (ml)	0.044	0.028	0.0222	0.056	0.044	0.0227	0.033	0.155	0.557
	0.188	0.135	0.0957	0.218	0.186	0.1014	0.136	0.564	0.226
Volume expansion ratio	-0.01	-0.01	-0.0002	-0.02	-0.015	-0.011	0.02	-0.02	-0.045
	-0.31	-0.29	0.016	-0.45	-0.403	-0.303	-0.47	-0.37	-0.933
Grain yield plant^{-1} (g)	0.169	0.03	0.1523	0.088	0.021	-0.085	0.053	0.166	-0.034
	0.195	-0.04	0.2544	0.09	0.003	-0.089	0.13	0.178	-0.001

4. CONCLUSION

The genotypes WGL 915 was identified for panicle length and panicle weight, filled seeds panicle^{-1}, JGL 21820 and CR 3985-1 for grain yield plant^{-1} and WGL 347 for panicle density and can be used in the varietal development programmes. Based on correlation studies, effective tillers, panicle density, panicle weight, milling (%), and head rice recovery can be considered during selection. Path analysis revealed that filled seeds panicle^{-1} and panicle weight had direct effect on grain yield plant^{-1}.

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